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CONSTRUCTING THE PALAEOVEGETATIONAL RECORD FOR THE BURIED SOILS IN THE HUNGARIAN YOUNG LOESS SEQUENCE: A VIEW FROM PHYTOLITH ANALYSIS

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Abstract

Paleoenvironmental investigations on the Hungarian Young Loess sequence (Upper Pleistocene) have been used to both infer paleoclimate and improve inter-regional correlations. These paleoenvironmental data, however, are insufficient to form the basis of such inductions. Paleovegetational and malacological studies have been scarce and results from different paleoenvironmental methods do not always agree. Moreover, these problems are compounded by numerous chronological revisions derived through various dating methods.

Phytolith analysis was applied to the Hungarian Young Loess sequence as a contribution towards the solution of these problems. Opal phytoliths were extracted from the MF and BD_1 buried soils of three Hungarian type-sites: Basaharc, Mende, and Paks. Intervening loess strata were also investigated. Because the specimens observed were highly weathered, no identification to the family level was possible. Nevertheless, vegetation community types were discernible. Previous paleoenvironmental investigations were then compared to the phytolith data obtained. The findings generally display more of an affinity towards palynological than malacological data.

According to the phytolith data, the MF soils developed under a relatively dry savannah environment. The loesses within the MF pedocomplex and between the MF and BD_1 soils were stabilised under non-arboreal vegetation. The BD_1 soils exhibit more variability. At Basaharc, it was primarily formed under non-arboreal (steppe) vegetation, while at Mende savannah prevailed. At Paks, this soil was subjected to different succeeding community types. These results complement and supplement existing paleoenvironmental records. They also aid in the interpretation of the buried soils and loesses by providing additional information on the environmental conditions responsible for their development.

Introduction

The loess exposures in the western part of the Great Hungarian Plain (Alföld) provide some of the best-preserved buried soil sequences in the world. Thus, they "are especially useful for comparative loess pedostratigraphy and, by inference, a record of

major parts of the Pleistocene climatic history of southeast Central Europe" (BRONGER and HEINKELE 1989, p. 171). Still, the understanding of the Quaternary environmental history of this record remains far from satisfactory. Disagreements exist among the available palaeoecological records from which paleoclimates have been inferred. In addition, the viability of buried soil correlations has been undermined by discrepancies between different dating methods.

The principal aim of this research is to contribute new data to the paleoenvironmental and paleoecological record of Late Pleistocene buried soils in Hungary. In the process, I attempt to rectify two salient problems: (1) the scarcity and insufficient resolution of paleovegetation studies and (2) irreconciled discrepancies between paleoenvironmental interpretations. For these purposes, the method of phytolith analysis was applied for the first time to this terrestrial record at three Hungarian type localities: Basaharc, Mende, and Paks.

Phytolith analysis permits the extraction of paleobotanical data from contexts where other botanical remains are seldom preserved (ROVNER 1971). Due to this advantage, phytolith analysis has been successfully employed in a variety of paleopedological and paleoenvironmental studies in many different areas of the world since the 1950's (PIPERNO 1988). Thus, phytolith analysis can contribute to a reinterpretation of this Late Pleistocene paleoenvironmental record. The new data also provide a basis whereby previous paleoenvironmental investigations can be evaluated (and possibly reconciled). As vegetation and other factors are more clearly understood, paleoclimatic interpretations become less speculative and the foundations for buried soil correlation are commensurably secured.

The Young Loess sequence

The Young Loess sequence, "the most complete of the stratigraphic series" in Hungary (PÉCSI and HAHN 1987, p. 95), ranges in age from at least the Mid Pleistocene to the last glaciation. The sites investigated are located in Central and North-Central Hungary. They are regarded as type localities for the entire sequence (PÉCSI and HAHN 1987; PÉCSI and SCHWEITZER 1993). The soils examined in this study belong to the lower Young Loess series, also known as the Mende-Basaharc Loess Complex, which can reach a 15 to 20 m thickness (PÉCSI 1993).

The soils analysed are known as the following: the MF pedocomplex, which is manifested as soils MF_1 and MF_2 at Mende; and the BD (Basaharc Double) pedocomplex, of which only the upper BD_1 soil was sampled. These pedocomplexes form part of a series of stratotypes more or less present at all the sites investigated. The MF_1 soil is considered a "poorly developed chernozem", the MF_2 soil "a well-developed forest steppe soil", and the BD_1 soil a "forest steppe soil" (PÉCSI, 1993, pp. 327–328).

Recent reexamination of the TL ages of some of these soils and sediments have somewhat complicated existing stratigraphic correlations. The Young Loess sequence stratotypes have received more confusing than compromising chronological revisions, however. What is certain, nonetheless, is that the soils are much more ancient than previously surmised.

Corroborated through aminostratigraphic analysis, recent TL analyses place the MF soils from Mende and Paks under the same time period (OCHES 1994, ZÖLLER *et al.* 1994). The similarity in age derived from other sites is used as the rationale whereby the MF/MF_1 soils can be confirmed as older than previously thought. Previous ^{14}C dates from all three type-sites also display approximate agreement, however. Unless all radiocarbon dates are proven to have been systematically underestimated, there appears to be no reason to consider TL dates as any more reliable. Consequently, I surmise that the earlier ^{14}C ages remain viable. As recent TL analyses indicate, MF_2 at Mende represents a much earlier soil-forming episode. This suggests an erosional hiatus between soils MF_1 and MF_2.

The newer TL results from the BD_1 soils suggest that their formation preceded the last interglacial. This evidence is further corroborated by relative ages obtained through the analysis of isoleucine racemisation from fossil gastropod shells. The amino acid geochronology constructed from the Paks exposure suggests that BD_1 could belong to the last or an even earlier Riss interstadial (OCHES 1994). ZÖLLER *et al.* (1994) further claim that the entire BD pedocomplex formed during the penultimate interglacial; however, I would argue that, given the evidence, one or both of these soils could just as likely belong to Riss interstadials.

Previous paleoenvironmental studies

Malacological analyses have been limited to the sites of Mende and Paks. The original interpretations of WAGNER (1979 a,b) need to be reassessed in accordance with recent data on gastropod ethology from LOŽEK (1990) and SZÖŐR *et al.* (1991). Hence, malacological data are presented in a reinterpreted form on *Table 1.*

Many palynological investigations have also been performed, but much of the focus has been on longer-term climatic patterns (cf. RÓNAI 1985). The work of PASHKEVICH (1979) and URBAN (1984) constitute the only palynological studies on the MF and BD soils to date. Since no loess units related to this discussion were examined by these authors, the phytostratigraphy of the Young Loess sequence remains tentative. Malacological results from loess 2 (the loess overlying BD_1) at Mende and Paks and from

soil BD_1 at Paks contradict palynological findings (*Tab.1*). The micromorphological interpretation of a warmer and drier environment for soil BD_1 at Paks (BRONGER and HEINKELE 1989) also finds no support in the molluscan data. Moreover, many sediments and soils at Mende and Paks have not been subjected to such research, while the site of Basaharc has been ignored.

As a consequence of these discrepancies, palaeoclimate cannot be inferred with any degree of confidence from these soils and sediments, even though the aim of such investigations has largely concentrated on the construction of paleoclimates. The data accumulated through these and the present methods are therefore best confined to the establishment of general paleoenvironmental patterns.

Phytolith analysis

Phytoliths constitute a variety of biogenically mineralised inter- and intracellular deposits which can occur in either calcareous (druses, raphids) or siliceous (plant opal) forms. Calcareous phytoliths are more susceptible to destruction through both weathering and erosion processes and no methodology for their extraction from soils and sediments has been devised (MULHOLLAND and RAPP 1992). Consequently, the siliceous version is generally considered the more viable source of information and has become the primary focus for this type of analysis.

Such deposits develop and accumulate within various plant tissues through the absorption of soil water solutes and subsequent transpiration-controlled translocation. One of these solutes, monosilicic acid, $Si(OH)_4$, contributes to the formation of opaline silica, $SiO_2 \cdot nH_2O$. Opal phytoliths are generally composed of 4-9% H_2O, 85-95% SiO_2, and a variety of impurities. A sizable amount of the latter can be present in the form of occluded organics derived from the cytoplasm. This constituent can exceed the percentage composition of all other trace elements combined and has been successfully utilised for ^{14}C dating (WILDING 1967, WILDING *et al.* 1977).

Opal phytoliths have a refractive index (R.I.) of 1.41–1.47 and are thereby discernible from glass shards (R.I.=1.48-1.61) under a polarising microscope. Their specific gravity ranges from 1.5 to 2.3. Biogenic opal is optically isotropic and displays no birefringence (JONES and BEAVERS 1963). Solubility (3 to 10 mg/l Si) is intermediate between other amorphous silica and silica-alumina gels and quartz (BARTOLI and WILDING 1980, WILDING *et al.* 1977, pp. 519–521). Opal phytoliths can reach a maximum diameter of 1,000 μm and a minimum of 1 μm (ROVNER 1983, p. 228).

As different portions of a plant, during its life cycle, either senesce or are severed and are thereafter digested through organismal activity, these biogenic deposits are released from their inter- and intracellular loci. Subsequently, they become incorporated into the soil as mostly solitary particles along with their associated organic matter.

Eventually, the entire plant ceases to live and the remaining body is consumed, thereby contributing more phytoliths to the soil.

Generally, phytoliths survive at a wider pH range than pollen, are resistant to changes in soil pH, and are not contingent upon sexually reproductive cycles (ROVNER 1971). However phytomorphic[1] differentiation rests completely on surficial features which are susceptible to dissolution and disarticulation. Problems related to preservation therefore become salient and complicate issues of interpretation. In this study, the degree of fragmentation, corrosion, and weathering precluded any possibility of identification below the general ecosystem level. Therefore, for the purpose of this analysis, only the most basic differentiation between arboreal and non-arboreal taxa was sought.

Established criteria for morphological differentiation between arboreal and non-arboreal phytoliths already exist (GEIS and JONES 1973; WILDING and DREES 1974). For instance, temperate deciduous species appear to produce diagnostic scrolled forms, cup-shaped, and spherical phytoliths. These contrast with the generally nodular (globular) forms prevalent in herbaceous taxa (GEIS and JONES 1973; ROVNER 1971; WILDING and DREES 1973 and 1974).

Phytolith assemblages can represent both allochtonous and autochtonous phytomorphs. It becomes difficult, therefore, to estimate the extent to which the local vegetation is represented in a paleosol, especially in a zone of high eolian particulate deposition. As in the loess regions of North America, the effect of eolian transport "may normalize grass phytolith distribution over a region" (FREDLUND *et al.* 1985, p. 152) such as the Alföld. Nevertheless, phytoliths remain less susceptible than pollen to eolian transport (GEIS 1973).

Methods

All soils investigated were sampled at 10 cm intervals whenever possible, but never exceeded 20 cm. Intervening loess strata were also sampled. Soil processing followed a combination of different methods learned from G.G. FREDLUND, I. ROVNER, and B. MIDDLETON (also cf. PEARSALL 1986; ROVNER 1971).

In order to address the specificity of the forms observed in these samples, I devised a descriptive nomenclature which also relies upon an amalgam of established classification schemes. Each category was defined qualitatively according to general shape characteristics, rather than geometric proportions. I assume that surficial features have dissolved as a result of prolonged exposure to alkaline conditions derived from soil

[1] Phytomorphs are distinguishable phytolith morphological units.

recalcification. Consequently, I interpreted globular and polyhedral forms as representing partially dissolved bilobates, crosses, and/or saddles (each of which are traceable to particular *Poaceae* tribes).

Ambiguities resulting from fracture and weathering allowed only a few categories to be considered for interpretational purposes. Diagnostics for grasses were seldom present in large amounts. However, the concomitant presence of bulliforms, polyhedra, globular forms, polylobates, sinuates, and cones increases the possibility of identifying a soil as having developed under a non-arboreal community. This view is supported by the predominance of more "solid polyhedral structures" and nodular forms found in herbaceous taxa, especially the *Poaceae*. This contrasts with the "generally thin (1–2 μm) fragile plate-shaped incrustations of cell walls" and sphere-shaped phytomorphs typical of soils under forested environments (GEIS 1973; WILDING and DREES 1974, p. 295).

I defined a low phytolith content (expressed as % of sediment weight) to be % and to signify a rarefied presence of herbaceous taxa. This assumption originates from the consistent finding of high phytolith contents in tandem with the dominance of herbaceous species (TWISS *et al.* 1969). Thus, a high percentage of grass phytoliths relative to arboreal types does not entail steppe vegetation dominance if the total phytolith content is too low (FREDLUND *et al.* 1985).

Results

Summary results from both previous and present investigations are displayed on *Table 1*. Phytolith content values are shown on *Table 2*. These percentage figures are determined by dividing phytolith extract weights by their respective total oven-dried sample weights. Sums of diagnostic non-arboreal and arboreal phytomorphs counted are provided on *Table 3*. These scores are weighted by multiplying each sum value by its associated pollen content value and dividing the ensuing figure by 100. These weighted figures are designed to integrate differences in phytolith content with actual counts. By so doing, sums of diagnostic phytomorphs can be compared more easily. For instance, the high number of non-arboreal phytoliths in MF_2 (0–20 cm), Mende, can be readily noted to be much less indicative of the dominance of herbaceous vegetation when weighted with the associated phytolith content percentage (*Tab. 3*).

Following the rationale of URBAN (1984), the phytolith content of each soil can be interpreted as representing the accumulation and integration of microfossils in stratigraphical order. This approach assumes the existence through time of a landscape sufficiently stable for the soils to act as aggrading receptacles. This assumption may be justified in a depositional sequence such as this one (CATT 1990). However, values for the relative abundance of phytoliths complicate this issue (*Tab. 2*).

Table 1. Results from previous and present paleoenvironmental investigations

		Basaharc		Mende		Paks	
Soil	Age (BP)*	Previous	Present	Previous	Present	Previous	Present
$MF_{(1)}$	≈30 ka (^{14}C)	❷Forest/Steppe	Forest→Savannah	❶Warm-Moist ❷Chernozem ❸Mollisol ❹*Pinus*,↑ *Artemisia*	NAV→Savannah	❶Cold ❷Degrad. Chern. ❸Udic Haplustoll ❹50% NAP	--------
MF?	≈69 ka (TL)	--------	--------	--------	NAV	--------	--------
MF_2	≈85-69 ka (TL)	--------	--------	❷Forest/Steppe ❸Argiustoll ❹↑ AP	Forest	--------	--------
l 2	≈85 ka (TL)	---------	Sparse NAV	--------	NAV	❶Moist-Cold ❹*Cerealia, Betula*	NAV
BD_1	≈148-100 ka (TL)	❷Entisol? ❸Udic Haplustoll	NAV	❷Forest/Steppe ❸Argiustoll ❹↑ AP, ↑ *Poaceae*	Savannah	❶Warm-Moist ❷Forest/Steppe ❸Udic Haplustoll ❹↑ *Artemisia*	Forest→Savannah

Legend:

AP: arboreal pollen

NAP: non-arboreal pollen

NAV: non-arboreal vegetation

❶Malacology

❷Soil Macromorphology

❸Soil Micromorphology

❹Palynology

l:: loess

↑ : high percentage (predominance)

→: change towards other community type

*all age estimates derived from Pécsi (1993) and Zöller et al. (1994).

Table 2. Phytolith content data (% of sediment by weight in grammes)

Stratum	Basaharc	Mende	Paks
MF1/MF	1.89*	1.22	N.S.
	1.19*	0.05	N.S.
MF loess	N.A.	0.05	N.S.
MF2	N.A.	0.01	N.S.
	N.A.	0.09	N.S.
	N.A.	0.001	N.S.
loess 2	0.96	0.17	2.13
BD1	1.74	1.60	0.30
	1.67	2.10	0.10
	0.60	N.S.	0.74

* soil MF at Basaharc is presumed to correspond with MF_1 at Mende.
N.A.= not applicable
N.S.= not sampled

The MF pedocomplex. The MF_2 soil at Mende exhibited extremely low quantities of phytoliths. The highest relative values were not consistently coincident with A horizons. Post-burial translocations may have occurred and/or contemporary ecosystem(s) may not have been sufficiently phytolith-productive. There appears to be no consistency to the value fluctuations observed and there exist too many variables, some of which cannot be addressed (e.g., pH), which may have differentially affected the different soils and loesses. (cf. FREDLUND *et al.* 1985, pp. 156–157).

At Basaharc, the MF soil contained some bulliforms[2] and a relatively high amount of spheres. Some bilobates (usually associated with *Panicoid* grasses) and polyhedra appear at the top of the soil and decrease downward. The soil may have thus mostly developed under savannah. Subsequently, it may have been predominantly influenced by steppe. This conclusion is supported by the decrease of phytolith content towards the lower part of the soil and the unchanged relatively high quantities of spheres. Weighted values also demonstrate a smaller difference between arboreal vegetation (AV) and non-arboreal vegetation (NAV) raw scores.

[2] Bulliform cells are water-storing mesophyll cells which silicify under high moisture conditions (ROVNER 1983).

Table 3. Phytolith content totals and weighted values

NAV: non-arboreal vegetation
AV: arboreal vegetation

Site	Stratum	Depth (cm)	Total NAV	Total AV	Weighted NAV	Weighted AV
Basaharc						
	MF	>50①	73	20	1.38	0.37
		50①	48	20	0.57	0.24
	loess 2	middle②	136	2	1.31	0.02
	BD1	0-20	33	0	0.57	0.00
		40-60	73	1	1.22	0.02
		70-95	64	3	0.38	0.02
Mende						
	MF1	10-20	59	17	0.72	0.21
	MF1	20-40	55	4	0.03	0.00
	MFlkö	middle②	55	0	0.03	0.00
	MF2	0-20	110	23	0.01	0.00
		20-40	64	9	0.06	0.01
		40-60	62	18	0.00	0.00
	loess 2	middle②	95	9	0.16	0.01
	BD1	0-20	64	11	1.02	0.18
		20-40	64	12	1.34	0.25
Paks						
	BD1	0-20	90	6	0.27	0.02
		30-50	60	24	0.06	0.02
		70-90	90	17	0.67	0.13

① samples extracted ≥50 cm above the MF-loess 2 boundary
② samples extracted approximately from the middle of the stratum

Soil MF_1 at Mende appears to have developed at first under a NAV and subsequently under sparse AV. This is deduced from the increase down the soil profile of bulliforms and polyhedra and the downward decrease in spheres. The higher sphere content coincides with a relatively sustained number of trichomes and polylobates and the appearance of a few cones and saddles. The phytolith content values confuse the matter, however. Very low values might suggest an increasing arboreal and/or shrub influence; but spheres decrease at the bottom of the soil (A_2 horizon), while NAV values remain relatively stable throughout.

Somewhat the inverse seems to have occurred to the MF_2 soil. The downward decrease in globular shapes correlates with similar decreases in bulliforms and cones. Spheres decrease in the middle of the solum (lower A_1 and upper A_2 horizons), but remain numerous in the upper A_1 and lower A_2 horizons. The decrease coincides with a slight increase in overall phytolith content. Trichomes are present throughout in relatively large quantities. It is possible that this soil developed under forested conditions gradually shifting towards a sparsely forested environment and thereafter reverting to a forest ecosystem. However, the very low phytolith content values indicate minimal presence of NAV throughout the development of the soil.

The loess strata. The loesses mostly formed under sparse NAV. The complete absence of spherical phytomorphs from the loess between soils MF_1 and MF_2 is quite suggestive of the presence of herbaceous taxa. The loess at Mende, between the MF and BD pedocomplexes, may have formed under an environment sufficiently humid for trees to grow, as the phytolith record attests. Alternatively, AV phytoliths may have been introduced through eolian processes.

The BD_1 soil. Ambiguous results were obtained from soil BD_1. At Mende, the extremely low amount of NAV diagnostics may indicate a forest environment. Most of the NAV phytolith assemblage is comprised by globular forms, signifying a high degree of surficial weathering. The relatively high phytolith content suggests that the soil probably developed under a savannah environment. Results from Paks indicate that the soil developed under AV and then NAV as a drier phase followed. The middle of the profile coincides with the lowest levels of NAV diagnostics and the highest levels for AV. The Basaharc evidence, however, suggests a predominance of NAV, based on the virtual absence of any spherical phytomorph. Although very few NAV diagnostics were found, the levels of crosses and saddles (associated with Chloridoid grasses) were higher than at other sites and were accompanied by high amounts of globular phytomorphs.

Discussion

Phytolith preservation was rather poor, probably as a result of recalcification from the overlying loess (BRONGER and HEINKELE 1989, p. 165). The resulting alkalinity

increased dissolution rates (KAUFMAN *et al.*, 1981). But despite adverse conditions of preservation, the phytolith record reveals broad vegetation community changes through time. From the integration of this phytolith record with previous paleoecological analyses a more complete environmental picture emerges for the various buried soils and loess deposits investigated (*Tab. 1*).

The MF pedocomplex. Soil MF_1 at the Mende site probably developed under steppe and was later modified by the appearance of several arboreal taxa. This is corroborated by both malacological and palynological data. Thermophilous and hygrophilous gastropods occur with sparse thermophilous trees and a predominance of steppe. From this, a relatively humid temperate environment can be deduced. Temperatures were probably high as well. It is likely that the soil was a Udoll or Ustoll (degraded chernozem).

Soil MF_2 formed under a forest ecosystem, according to both palynological and phytolith data. This somewhat contradicts BRONGER and HEINKELE's (1989) assessment. They consider this soil to represent an Argiustoll, as a consequence of a relatively high clay content in the B horizon. Presumably, this would constitute a cambic horizon. However, no data are furnished to support this proposition. Furthermore, according to the results of PÉCSI–DONÁTH (1979), only a 1 to 2 % clay increase is documented for this purported B horizon. This suggests that despite a predominance of AV very little clay translocation occurred.

At the Mende site, in summary, aeolian processes began to dominate as the forest overlying the MF_2 soil gradually disappeared. Loess then formed under probably a sparse grass vegetation. The relative aridity which ensued may have only slightly decreased when the MF_1 soil began to form. In the north-central part of the Alföld, therefore, the more recent interstadial may have been slightly drier than the two preceding it.

Malacological and palynological studies are lacking for the Basaharc site. For soil MF, phytolith data indicate a forested environment succeeded by savannah. This agrees with the interpretation of the MF as a dark-brown forest steppe soil; but other paleoenvironmental analyses should be performed to ascertain this. Humidity values should at least have been sufficiently high for tree growth at this site. Soil MF probably continued to develop during the succeeding interstadial, contemporaneously to soil MF_1 at Mende. TL ages from ZÖLLER *et al.* (1994) corroborate this view.

This contrasts with the more southern site of Paks, where soil MF is interpreted as a Udic Haplustoll. Palynological data support this view, but the gastropods appear to be more cryophilous than thermophilous. With the aid of further phytolith analysis this contradiction could be redressed.

The loess strata. The loess intercalating the MF and BD pedocomplexes presents an interesting quandary. At Basaharc, the prevailing phytomorphs suggest a NAV, although the total phytolith content is rather low. Malacological data from Paks indicate the presence of gastropods who can withstand a high range of temperatures. Finally, at the Mende site, the loess samples exhibit some indication of the scarce presence of trees.

The high phytolith content indicates a predominance of grasses. According to the palynological data, they are mostly thermophilous. The gastropod assemblage also points to a relatively warm and humid phase. It would appear that loess formed under a prevailing steppe ecosystem with the occasional tree contributing to surface stabilisation.

The BD_1 soil. The BD_1 soils are claimed to represent the last interglacial. However, at Basaharc, this "interglacial" hypothesis finds little support. The phytolith data indicate that it formed under NAV, in contrast to the more arboreal MF soil. The BD_1 soil appears to be an AC-type, probably an Entisol. It is much thinner than the overlying MF soil, which is also interpreted as an interglacial episode (BRONGER and HEINKELE 1989; ZÖLLER *et al.* 1994). Moreover, because BD_1 retained an A horizon, erosion cannot be invoked as the source of these soil development differentials. The proponents of the "interglacial" hypothesis have yet to explain this interpretational discrepancy.

The paleoenvironmental data from Paks yield a rather confused picture. Malacological and phytolith evidence indicate a forest ecosystem, probably open, and moist warm conditions can be surmised. The high values for *Artemisia* contradict these and soil morphology appear to concur with palynological data.

The contradiction might be a function of sampling, however. Previous malacological and palynological investigations involved a single sample per soil. These sample locations within the soil profile might coincide with any of the phytolith sampling intervals. As can be seen on *Table 3*, an alternation of NAV and AV dominance occurred. The results from malacological and palynological investigations might happily coincide and agree with any one of these three phytolith sampling intervals. Of course, the opposite might just as well be the case.

At the Mende site, BD_1 probably developed under a savannah environment. This agrees with both palynological and micromorphological data and the presence of a Bt horizon postulated by BRONGER and HEINKELE (1989).

Implications. Generally, the results from phytolith analysis concur with previous paleoenvironmental data (*Tab. 1*). The exceptions at MF_1 (Mende) and BD_1 (Paks) only concern gastropod analysis. This is not surprising, as malacofauna are notoriously representative of very localised areas (cf. ROUSSEAU 1992). The agreement between palynological and phytolith data is due to their relatively similar modes of diffusion. As a differentially subsiding basin, the Alföld acts as a receptacle for the influx of allogenic particulates. Therefore, the phytolith assemblages observed, like pollen frequencies, should represent areas larger than the immediate sites investigated.

The environmental variability noted between "contemporary" soils can be explained by geomorphological and local climatic differences. These differences probably resulted from the location of these sites in different ecotones (PÉCSI 1970). Basaharc is situated just within the Transdanubian mountainous forest belt (PÉCSI and HAHN 1987), while Mende and Paks lie in a low order river valley and a subsiding floodplain respectively. Therefore, the pedomorphological and palaeobiological characteristics

observed in the soils analysed should be expectedly diverse. As a consequence, the value of considering these sites as regional representatives for the Alföld is questionable[3].

As far as chronological issues are concerned, the newer TL ages for the "interstadial" MF_2 soil at Mende appear to contradict phytolith data. Though indicating the possibility of very humid conditions, the phytolith data do not support the contention that this soil developed through two interstadials (ZÖLLER *et al.* 1994). That is, the phytolith assemblage do not change appreciably within the soil.

Finally, an integration with other biostratigraphical records enables one to address several methodological problems. For instance, the prevalence of NAV phytoliths in a stratum might not indicate an actual NAV dominance (FREDLUND *et al.* 1985, p. 159). Results from earlier palynological investigations mostly concur with the phytolith record and it can thus be concluded that at these sites the underrepresentation of arboreal taxa is not a hindrance to the analyst.

Problems related to equifinality of soil morphology under different ecosystems can also be obviated. As MOFFET *et al.* (1994) reported in a study of North Dakota soils under a variety of phytocoenoses, soil morphology may reflect development under an unexpected vegetation type. An agreement between palynological and phytolith data increases the certainty of a paleoenvironmental interpretation.

Summary and conclusion

Despite the amount of attention the Hungarian loess sequence has received, many problems remain unresolved, especially those related to basic paleoenvironmental considerations. Part of the solution to this problem involves a more reliable assessment of the paleophytocoenoses partially responsible for the formation of paleosols and loess deposits. Resolving such fundamental issues will increase the viability of paleoenvironmental interpretations.

Phytolith analysis was applied for the first time to the sites of Basaharc, Mende, and Paks, where palaeobotanical studies are conspicuously incomplete. These Hungarian type localities represent the lower part of the Upper Pleistocene Young Loess sequence. The MF pedocomplex and soil BD_1 were investigated for their phytolith content. It was found that phytolith analysis complements and supplements current palaeoenvironmental data. The results demonstrate the existence of different vegetation communities co-occurring through time at each site.

[3] Alternatively, this diversity within the same period might be explained by the possibility of miscorrelation. Given the extreme fluctuations in age estimates, this hypothesis might not be so incredible.

Due to poor preservation and the absence of absolute counts, these results should be considered tentative. Nevertheless, the phytolith data generally agree with the results from other palaeobiological studies, excepting soil BD_1 at Paks and soil MF_1 at Mende. The BD_1 soil at Basaharc developed under NAV (non-arboreal vegetation) while the one at Mende formed under a savannah-type environment. At the latter site, the more locally specific malacological and phytolith data suggest a warm and moist environment tending to savannah prior to burial.

The MF pedocomplex at the Mende site consists of two soils with an intervening long erosional hiatus. Both the MF_1 soil formation and underlying loess stabilisation episodes occurred under a NAV (probably steppe) environment. The latter appears to have been a drier phase according to the type of grass assemblage noted.

Phytolith and other palaeoenvironmental records indicate a high degree of environmental diversity for soils deemed to have been developed under similar climatic conditions (cf. BRONGER and HEINKELE 1989). Current soil interpretations need to be reconciled with these data. These results also contribute indirectly to issues related to both inter-regional correlation problems and the understanding of the paleoenvironments of the Carpathian Basin. More research integrating a variety of paleoenvironmental methods will increase the possibility of describing the sets of pedogenetic variables responsible for the morphological features observed in the buried soils examined.

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